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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

ORIGINALLY ISSUED

March 1943 as
Advance Restricted Report

WIND-TUNNEL TESTS OF TWO TAPERED WINGS WITH STRAIGHT

TRAILING EDGES AND WITH CONSTANT-CHORD CENTER

SECTIONS OF DIFFERENT SPANS

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WASHINGTON

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WIND-TUNNEL TESTS OF TWO TAPERED WINGS WITH STRAIGHT TRAILING EDGES AND WITH CONSTANT-CHORD CENTER SECTIONS OF DIFFERENT SPANS

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SUMMARY

Tests were made in the NACA 19-foot pressure tunnel to determine the aerodynamic characteristics of two tapered wings having NACA 230-series airfoil sections, constant-chord center sections, and straight trailing edges. The wing spans, the areas, and the root chords of the two wings were equal; the span of the center section of one wing was equal to the root chord and the span of the other was twice the root chord. Lift, drag, and pitching-moment characteristics of the wings with partial-span and full-span split flaps are given for a test Reynolds number of 4,600,000.

The maximum lift coefficients of the wing with the square center section were greater, for all arrangements tested, than those of the wing with the rectangular center section; also, with flaps neutral the drag coefficients were smaller for lift coefficients greater than 0.1. The aerodynamic-center positions of the plain wings were found to be 0.451 of the mean chord from the leading edge for the wing with the square center section and 0.442 of the mean chord from the leading edge for the wing with the rectangular center section.

INTRODUCTION

The nonlinear distribution of area and of section aerodynamic centers along the span of a wing is of utmost importance in airplane design because of its influence on the location of the wing aerodynamic center. Previous research reported in reference 1 provides data for wings with either a nonlinear distribution of area or a nonlinear distribution of aerodynamic centers. The present

tests were made at the request of the Bureau of Aeronautics, Navy Department, to provide data on conventional wings with both variables and were limited to wings with constant-chord center sections and straight trailing edges. The effect of center-section span was determined.

Complete lift, drag, and pitching-moment characteristics were determined for each wing through a range of Reynolds number of 2,600,000 to 4,600,000. The characteristics with partial-span and full-span simple split flaps were determined. In addition, a study of the stall characteristics was made.

MODELS

Wings

The models used in these tests were provided by the Bureau of Aeronautics according to NACA specifications and are designated wing III and wing VI. The wings are constructed of laminated mahogany to NACA 230-series airfoil sections and differ only in center-section span and sweepback. (See figs. 1 and 2.) The center section of wing III has a span equal to the root chord and that of wing VI has a span twice the root chord. The spans, root chords, areas, and aspect ratios of the two wings are equal. The airfoil sections used were the NACA 23015 for the center section and the NACA 23009 for the construction tip. In the construction of the wings, straight-line elements were used between corresponding points of the root and the construction-tip sections in such a manner that the upper surface at the maximum ordinate is in a horizontal plane. No geometric twist is present.

The principal characteristics of the two wings are:

	Wing III	Wing VI
Aspect ratio	7	7
Center-section span	1.27 S/b	2.54 S/b
Root chord	1.27 S/b	1.27 S/b
Tip chord	.635 S/b	.444 S/b
Taper ratio (outer panels only)	2.0	2.86
Sweepback, Λ , degrees	9.44	15.53

The ratio S/b, which is equal to the mean chord of the wing, is the ratio of the wing area to the wing span.

Flaps

The flaps were simple split flaps constructed of thin metal sheet and had a chord 20 percent of the wing chord. The desired deflections were obtained by inserting triangular wooden blocks between the wing lower surface and the flap. The spans of the partial-span and full-span flaps were 53 percent and 90 percent of the over-all wing span, respectively.

TESTS

The tests were conducted in the NACA 19-foot pressure tunnel at an absolute pressure of 35 pounds per square inch with the model mounted on the standard wing supports. (See fig. 3.)

Complete lift, drag, and pitching-moment characteristics were determined for the wings with no flaps; with the partial-span flaps at deflections of 15°, 30°, 45°, and 60°; and with the full-span flaps at 60°. The tests were made at test Reynolds numbers of approximately 2,600,000, 3,600,000, and 4,600,000.

A study of the stalling characteristics was made by observing the behavior of wool tufts attached to the upper surface of the wing. These tufts were fastened to the surface at the 20-, 30-, 40-, 50-, 60-, 70-, 80-, and 90-percent-chord points in parallel rows spaced approximately 7 inches apart along the span. The progression of the stall was recorded by sketching the stalled portions of the wing at various angles of attack. The observations were made at a Reynolds number of 4,600,000 for the plain wings and for the wings with the partial-span flaps deflected 60°.

RESULTS AND DISCUSSION

Coefficients

The data presented herein are given in standard nondimensional-coefficient form corrected for the effect of model support tares and interference, air flow misalinement, and for jet-boundary effects.

The coefficients and symbols used herein are defined as follows:

C_L lift coefficient (L/qS)

C_D drag coefficient (D/qS)

C_m pitching-moment coefficient about quarter-chord point of root section $(M/qS\bar{c})$

where

L lift

D drag

M pitching moment

q dynamic pressure of undisturbed air stream $(1/2\ \rho V^2)$

S wing area (32.14 sq ft)

$\bar{c}$ mean wing chord (S/b = 2.14 ft)

c wing section chord

b wing span (15 ft)

ρ mass density of air

V free-stream velocity

and

δ_f flap deflection measured between lower surface of wing and flap

α angle of attack of root chord corrected for jet-boundary interference

R test Reynolds number based on mean wing chord $(\rho V\bar{c}/\mu)$

μ coefficient of viscosity

Precision

The experimental results as determined from repeat

tests are believed to be accurate within the following limits:

α, degrees . . . . ± 0.1

$C_{L_{max}}$ . . . . ± 0.03

C_m . . . . ± 0.005

$C_{D(C_L=0)}$ . . . . ± 0.0003

Lift and Stalling Characteristics

Complete force-test data for a Reynolds number of 4,600,000 are presented in figures 4 and 5. Comparison of the lift curves reveals that wing III has a higher angle of stall than wing VI for all conditions; and the maximum lift coefficients, consequently, are greater. The variation of maximum lift coefficients with Reynolds number is shown in figure 6. No consistent variation is indicated by these results, probably because of the unsteady manner in which the wings stalled.

The stall diagrams for the various conditions are shown in figures 7 to 10. The progression of the stall of wing III with no flaps is fairly rapid although not sudden. With the partial-span flap, the stall of wing III is very sudden, covering most of the right wing. The stall of wing VI with flaps off started at both wing tips and moved inward gradually. The stall of wing VI with flaps was similar.

It is evident that the maximum lift coefficients of the two wings could be materially increased, especially for wing VI, by using washout toward the tips to prevent early stalling.

Drag Characteristics

A comparison of the drag coefficients of the two wings with flaps off is shown in figure 11. Increasing the span of the center section increased the drag coefficients to some extent for lift coefficients greater than 0.1. The maximum variation was about 0.0015.

Pitching-Moment Characteristics

The effect of the nonlinear distribution of area and aerodynamic centers on the pitching-moment curve is shown in figure 12. The pitching-moment curves of the two models tested are given, together with the moment curve of a wing with no sweepback of the quarter-chord points. For the wing with no sweepback, it is assumed that the pitching-moment coefficients about the quarter-chord point are constant. It is seen that sweepback gives the pitching-moment curves a considerable negative slope, which indicates a rearward movement of the aerodynamic centers. The slope of the pitching-moment curve for wing III is greater negatively than that for wing VI. This same result is noted for the wing with partial-span and full-span flaps.

The positions of the wing aerodynamic centers, measured from the leading edge of the root section, were determined both from experimental data and from calculations. A comparison of these results is given in the following table:

Wing	Position of aerodynamic center back of leading edge (S/b)	
	Experimental	Calculated
III	0.451	0.460
VI	.442	.442

The aerodynamic-center positions were computed from the experimental data by the method outlined in reference 1. An average slope of the pitching-moment curve was used. The calculated aerodynamic-center positions were determined by the method of reference 2.

The aerodynamic-center position for comparable wings with no sweepback is approximately 0.318 S/b from the leading edge.

CONCLUSIONS

From the results of the tests reported herein, the following conclusions are drawn:

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1. The maximum lift coefficients of wing III were greater than those of wing VI for all conditions tested, because of the later stalling.

2. The effect of increasing the span of the center section while keeping the wing span, the root chord, and the area constant and the trailing edge straight is to shift the aerodynamic center toward the leading edge.

3. The horizontal positions of the aerodynamic centers as determined by experiment and by calculation from section characteristics are in close agreement.

4. Increasing the span of the center section increased the drag coefficients for lift coefficients greater than 0.1. The maximum variation in drag coefficient was approximately 0.0015.

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REFERENCES

1. Anderson, Raymond F.: The Experimental and Calculated Characteristics of 22 Tapered Wings. Rep. No. 627, NACA, 1938.

2. Jacobs, Eastman N., and Rhode, R. V.: Airfoil Section Characteristics as Applied to the Prediction of Air Forces and Their Distribution on Wings. Rep. No. 631, NACA, 1938.

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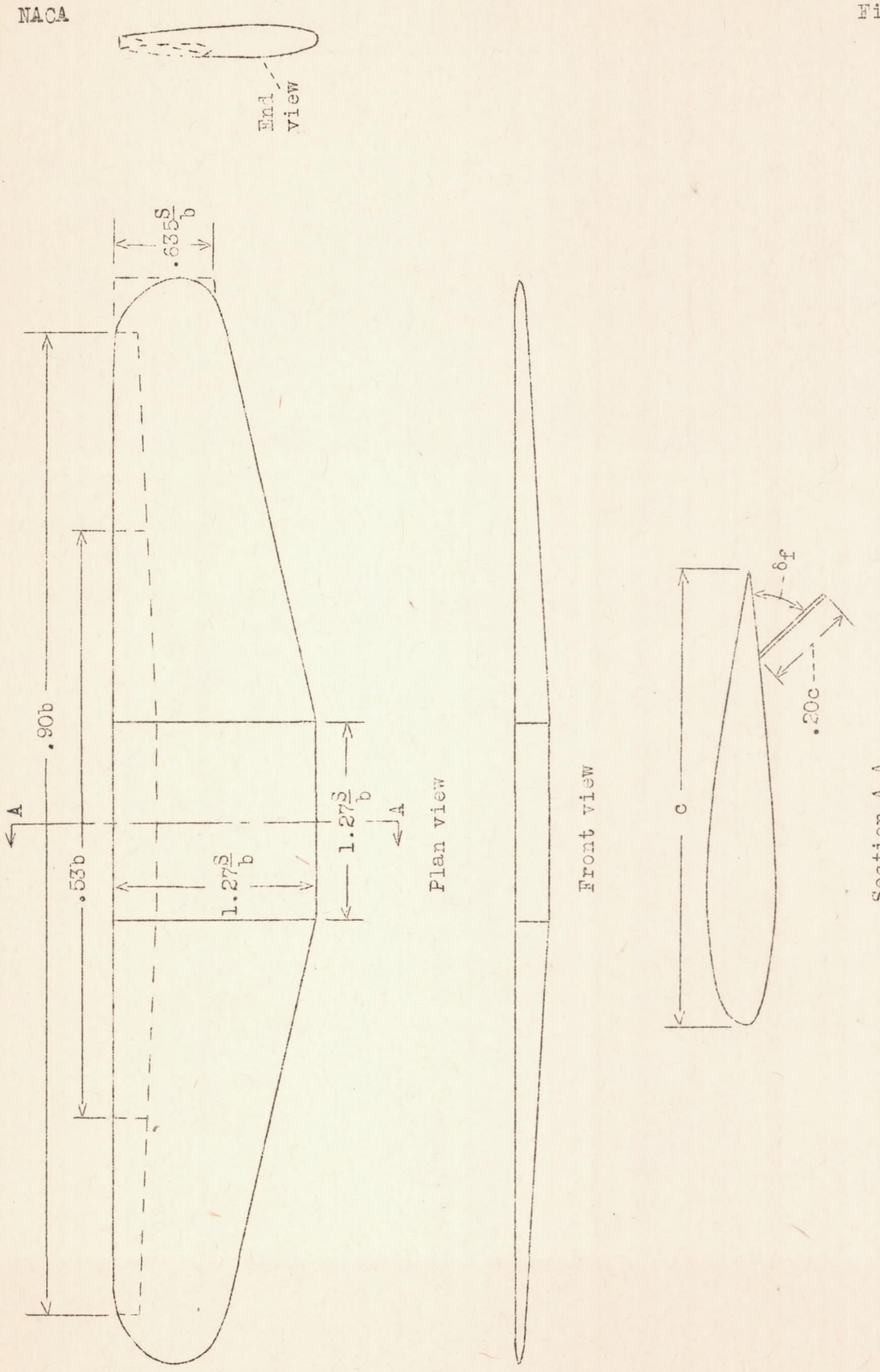

Figure 1.- Wing III.

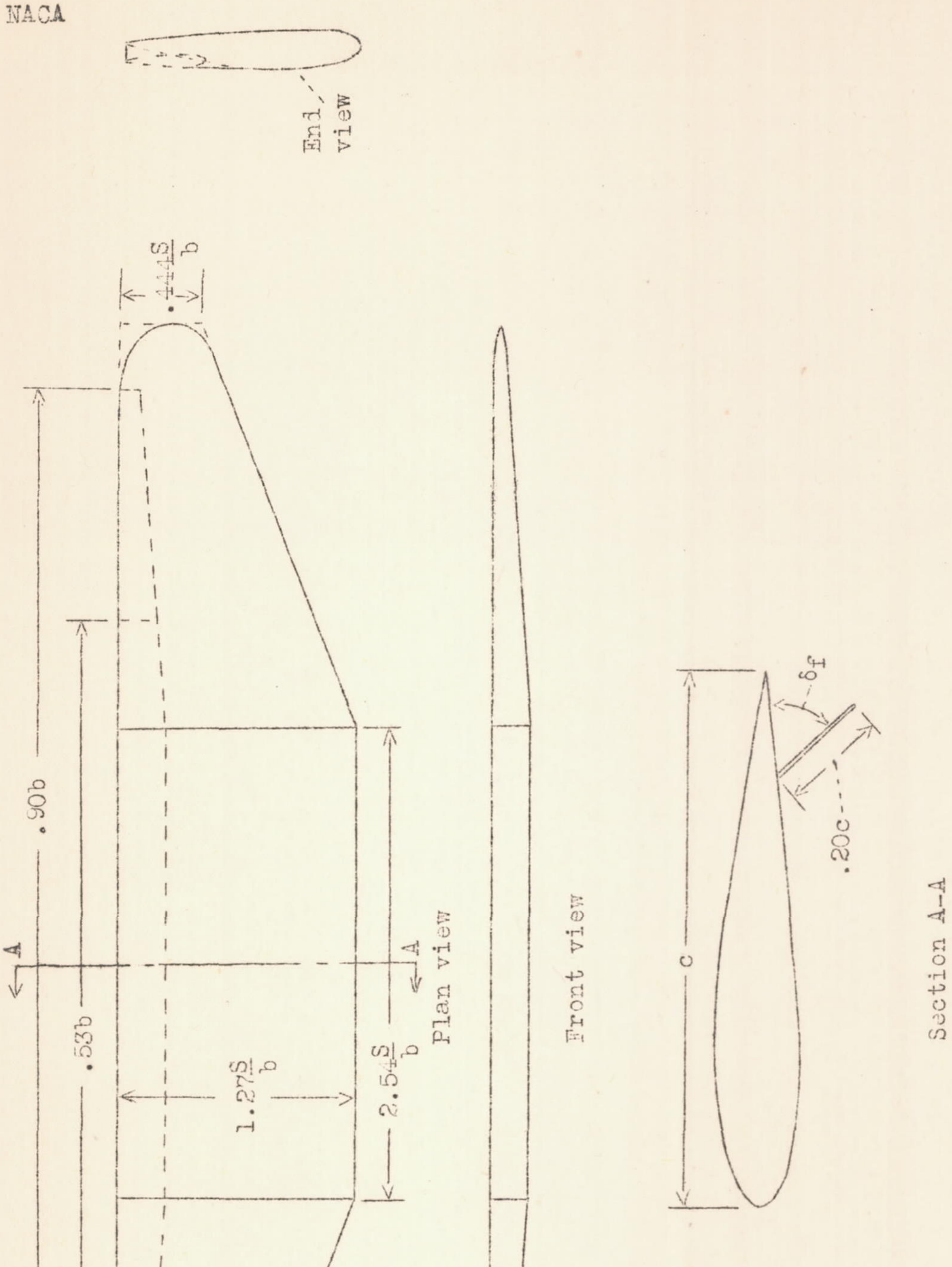

Figure 2.- Wing VI.

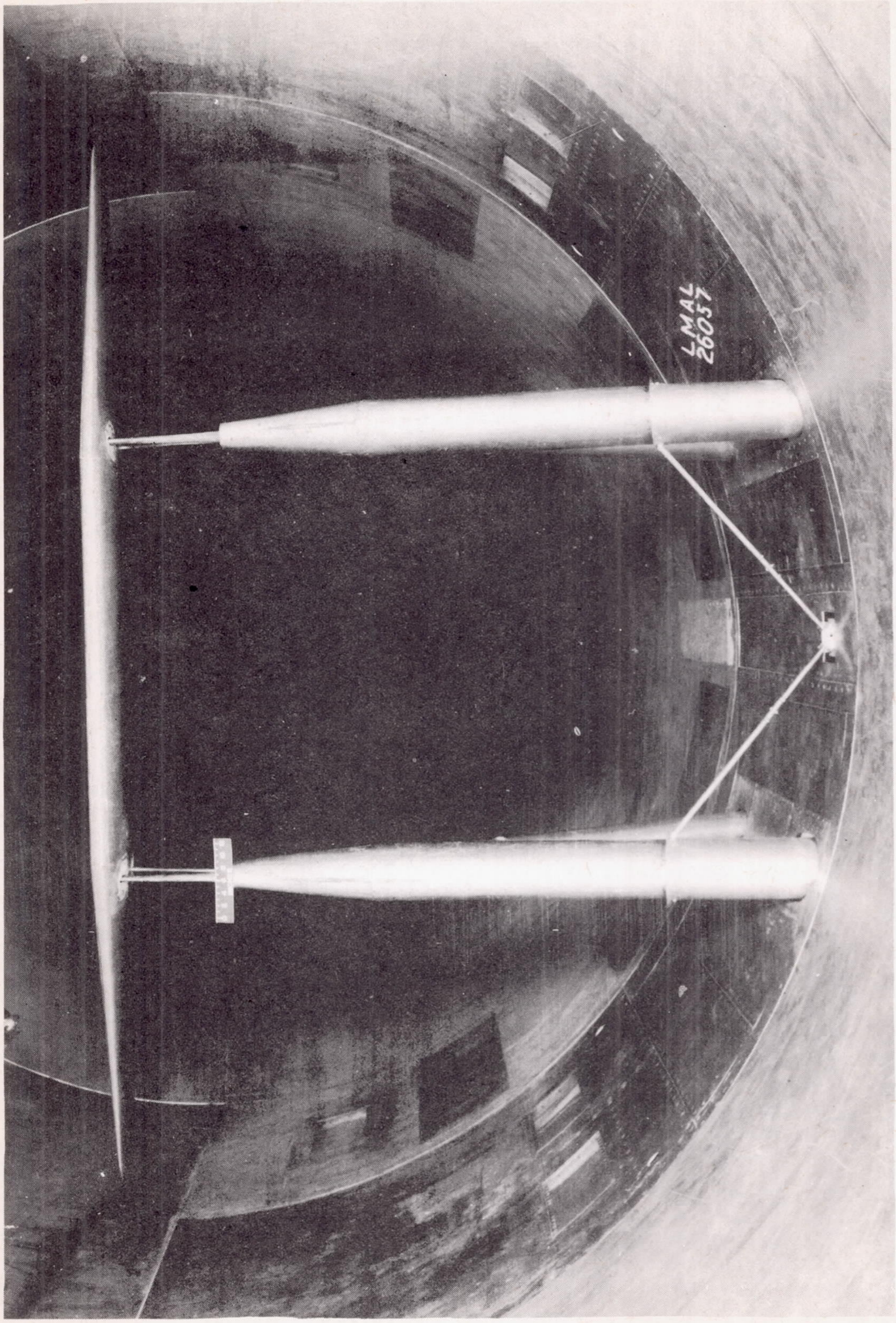

Figure 3.- Wing VI mounted in the 19-foot pressure tunnel.

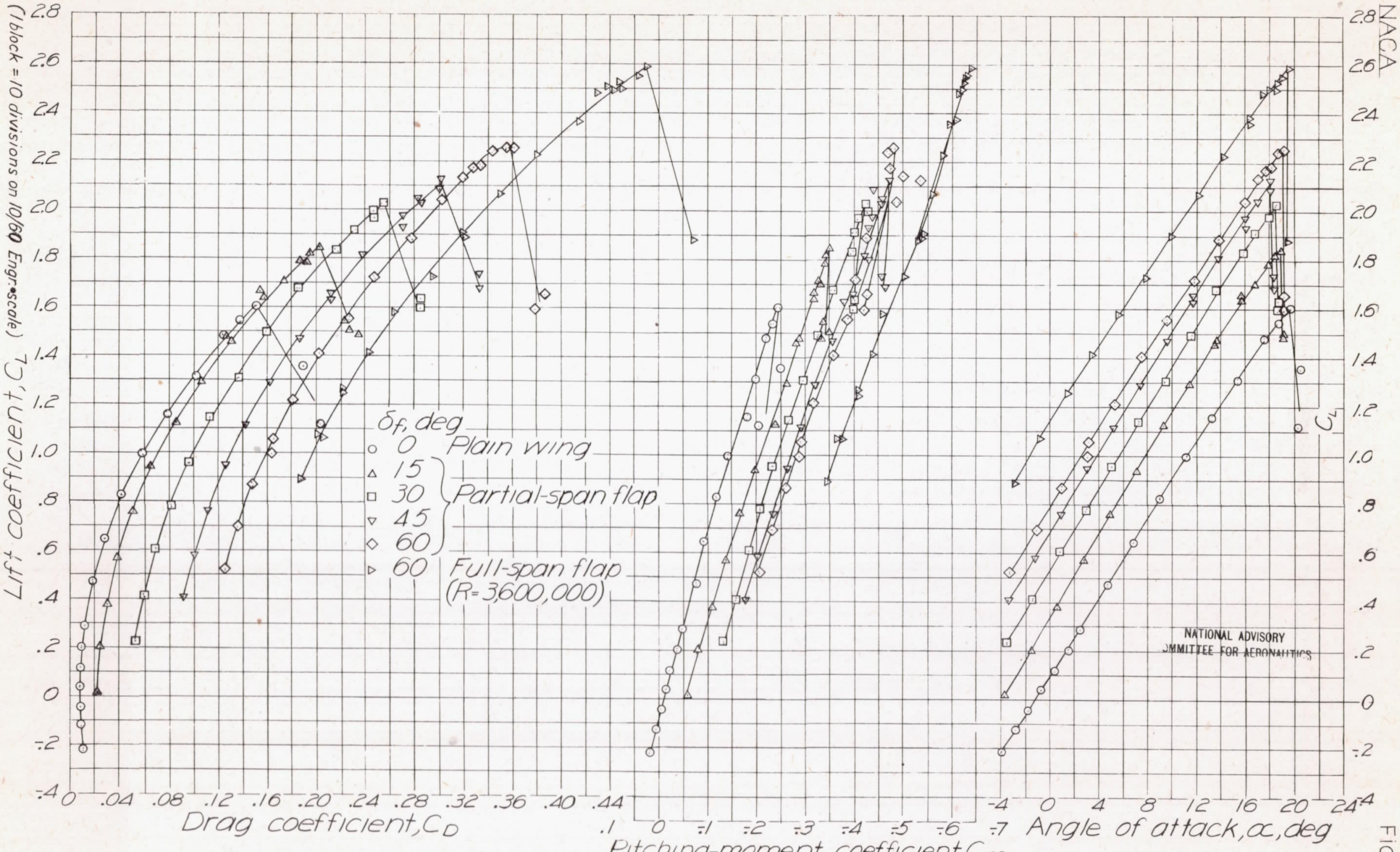

Figure 4.- Aerodynamic characteristics of wing III with 0.20c split flaps. R=4,600,000.

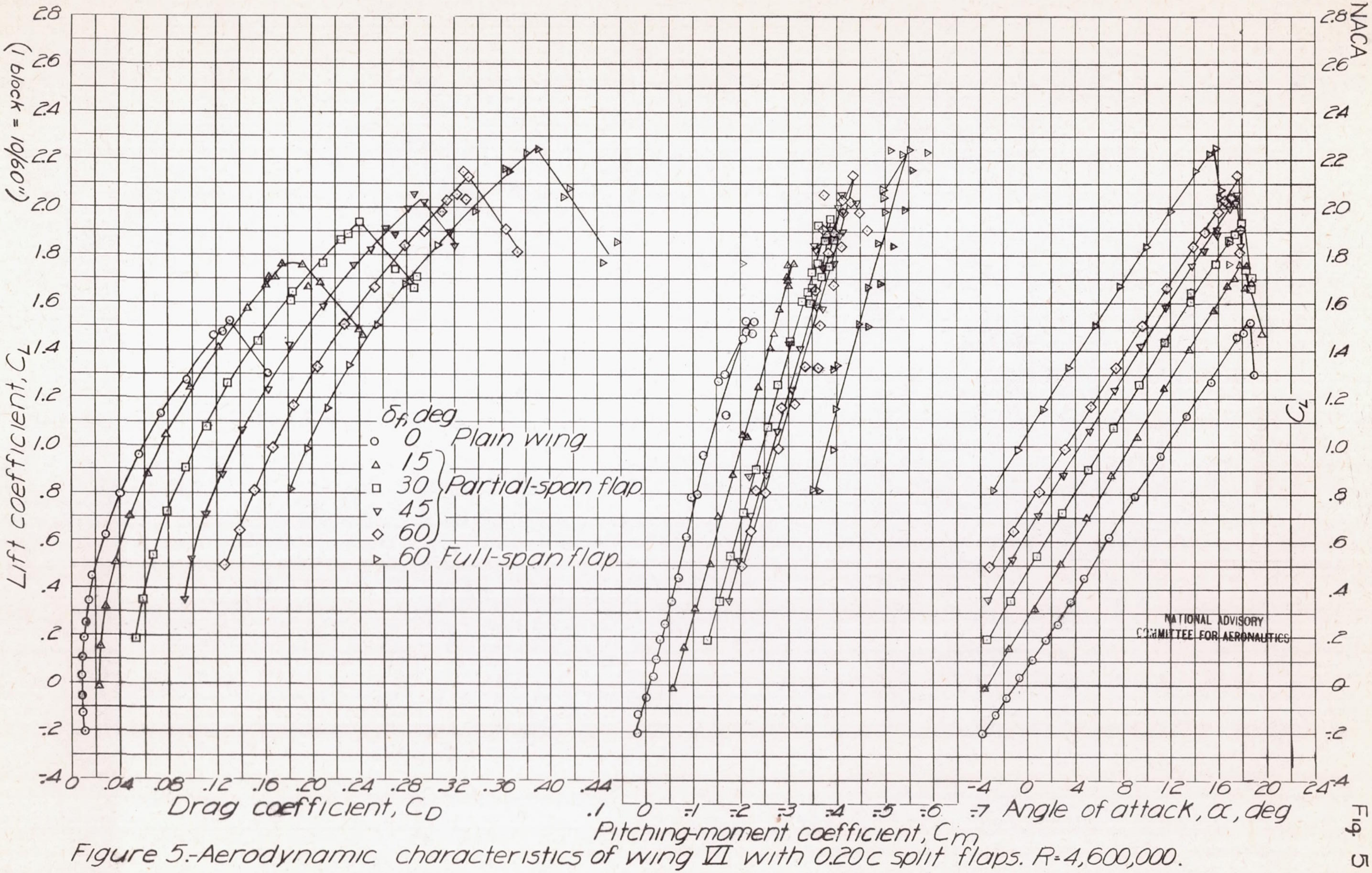

Figure 5.-Aerodynamic characteristics of wing VI with 0.20c split flaps. R=4,600,000.

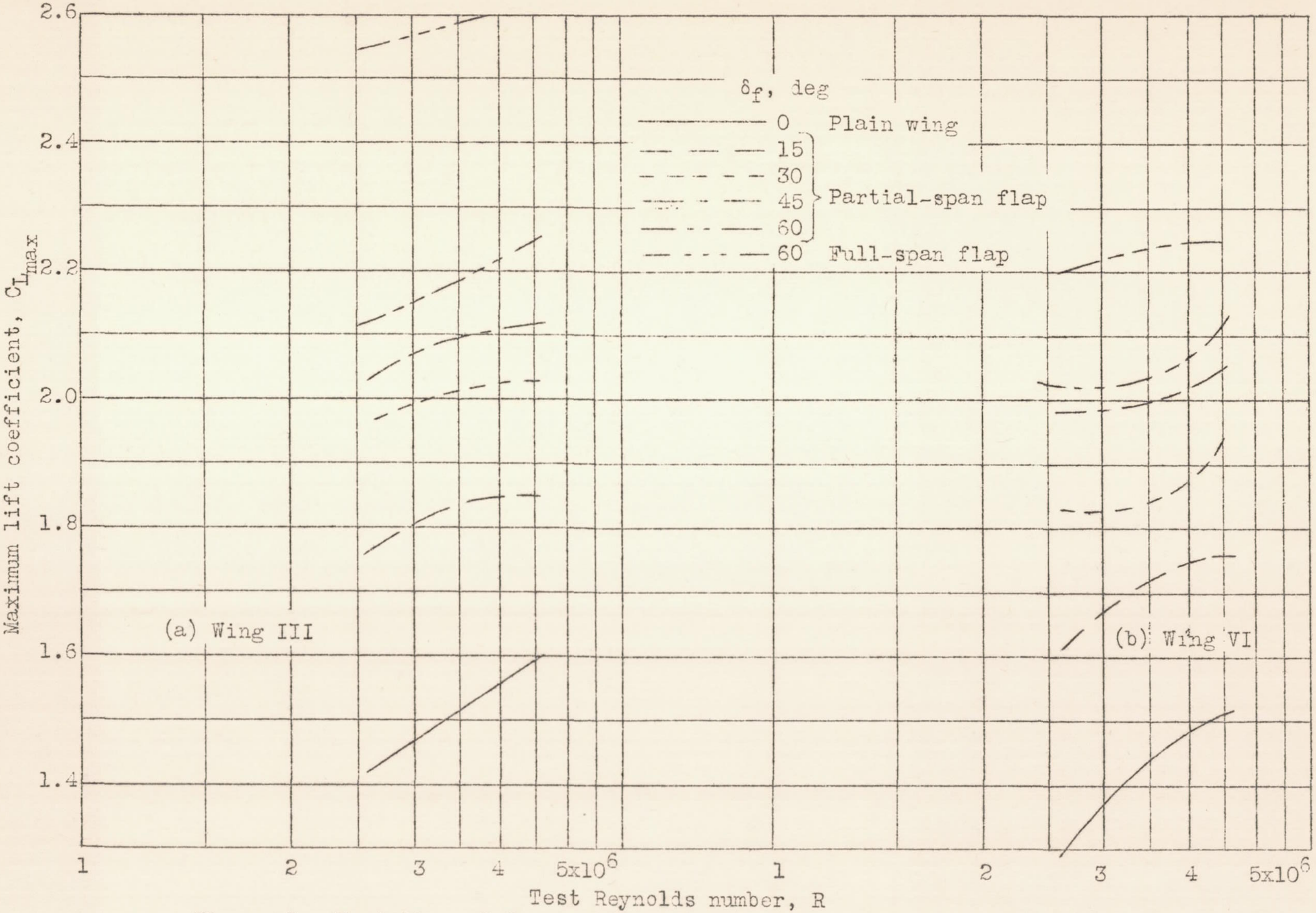

Figure 6.- Variation of $C_{L_{max}}$ with Reynolds number for wings III and VI.

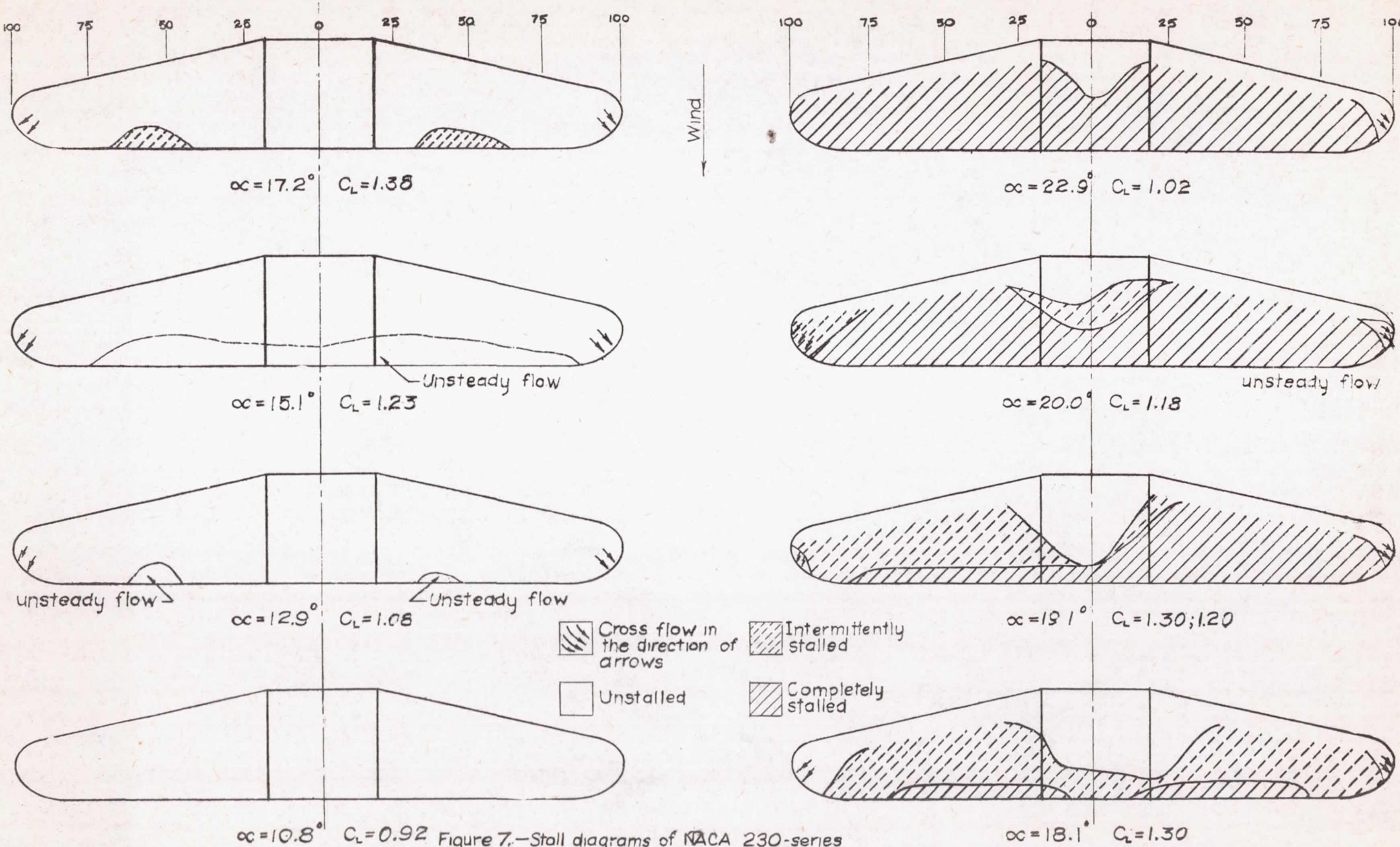

Figure 7.—Stall diagrams of NACA 230-series tapered wing III; plain wing; R = 4,500,000.

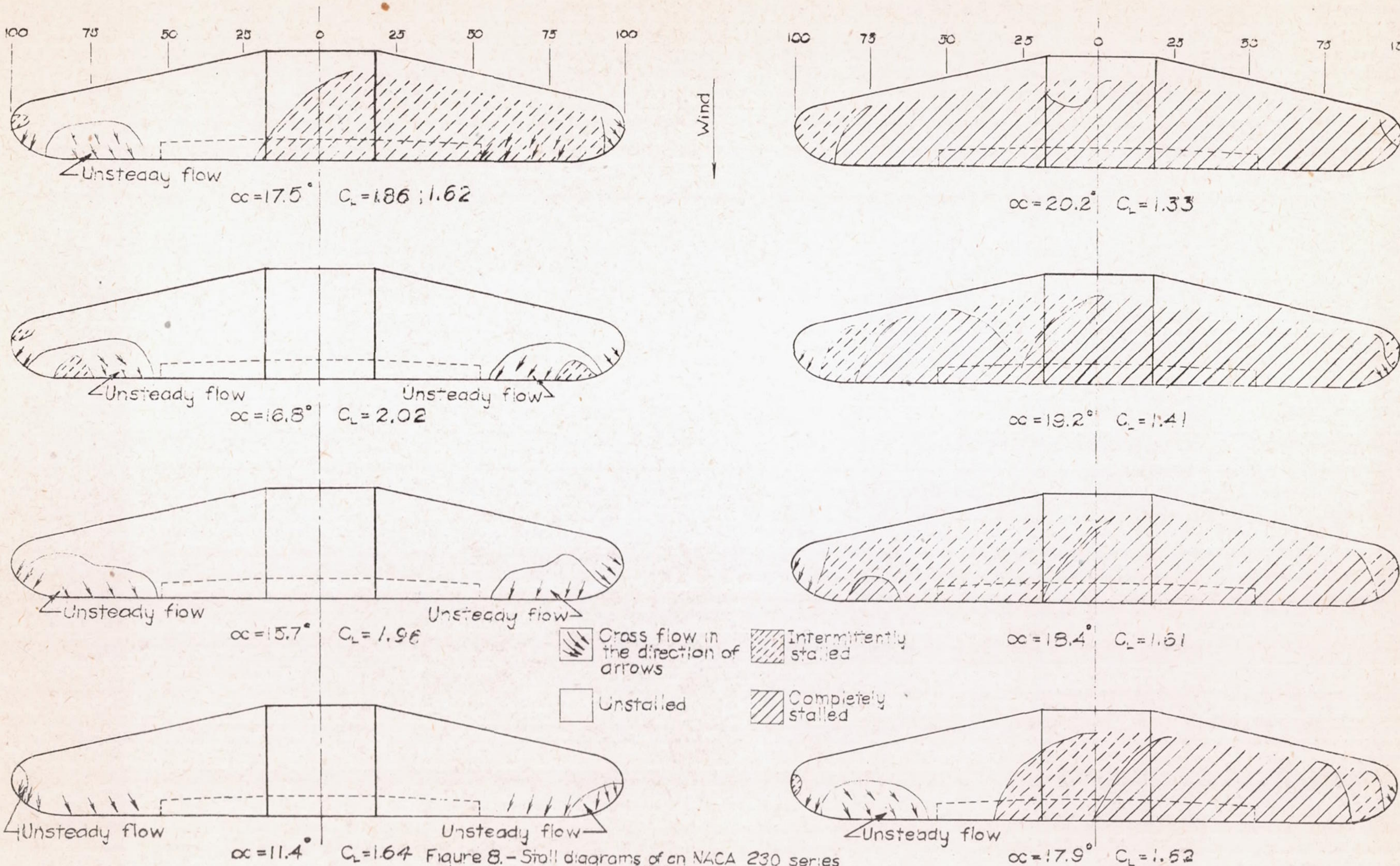

Figure 8.- Stall diagrams of an NACA 230 series tapered wing III with a 0.20-chord partial-span split flap. $\delta_f = 60°$; R = 4,400,000.

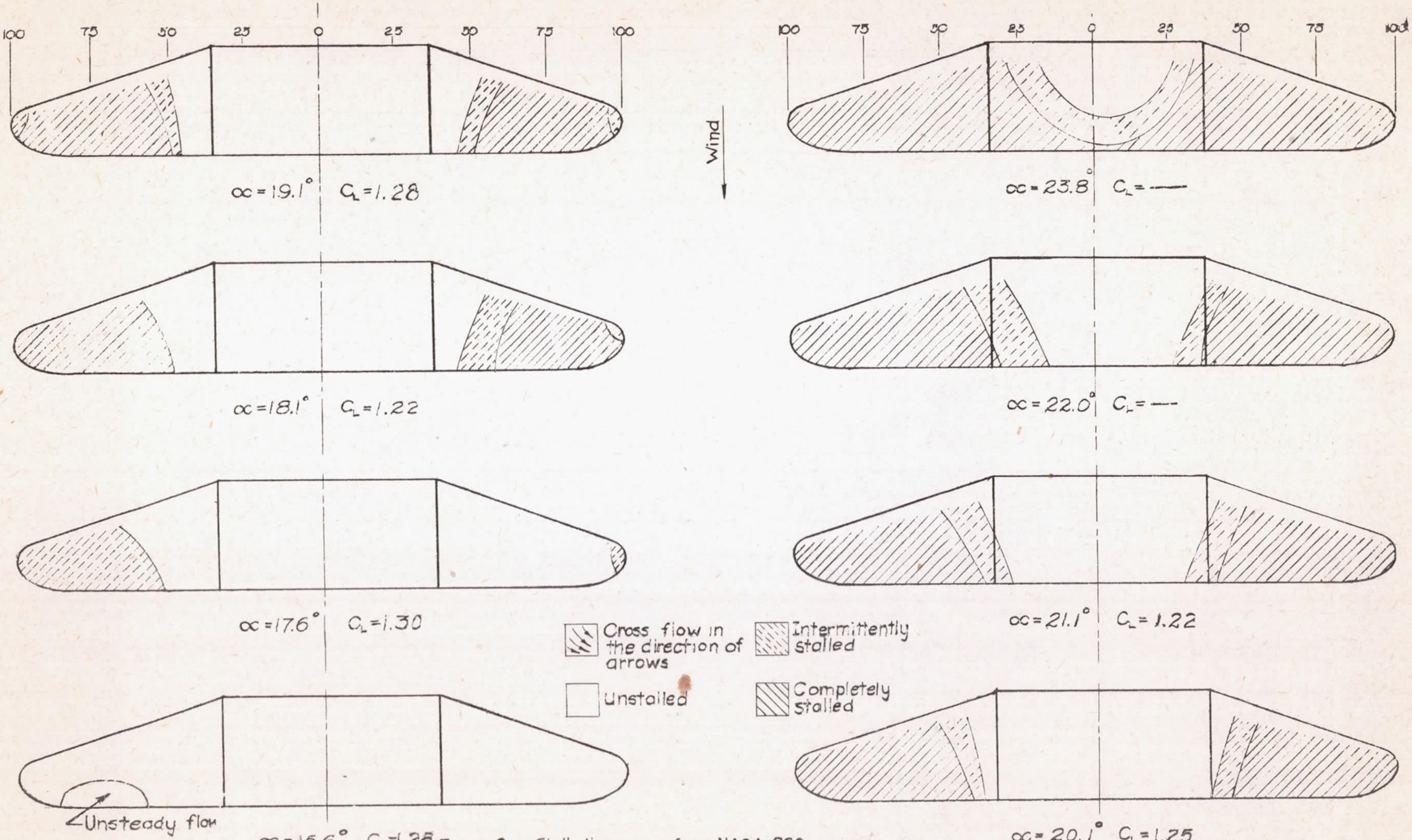

Figure 9.– Stall diagrams of an NACA 230-series tapered wing VI. Plain wing; R = 4,600,000.

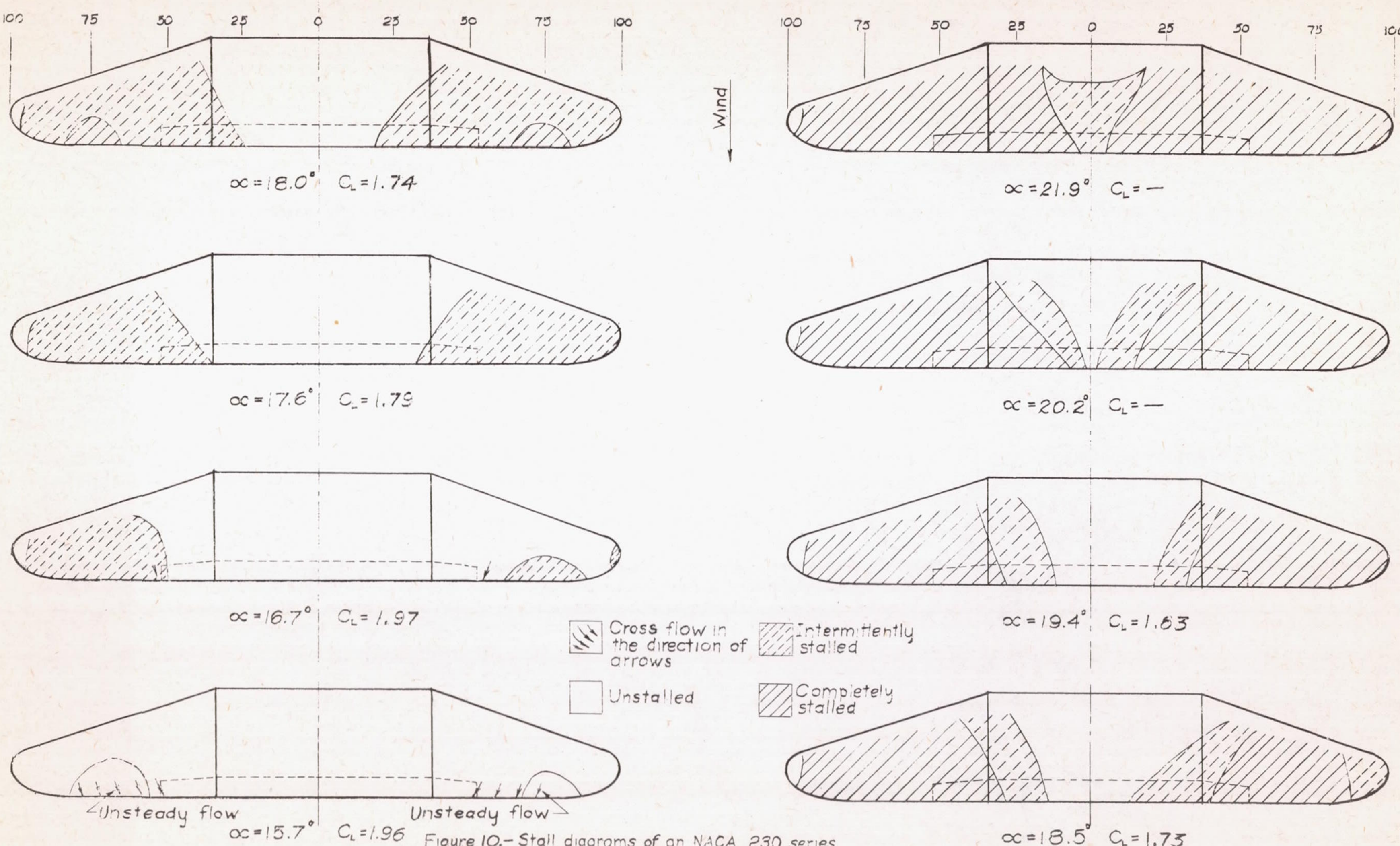

Figure 10.- Stall diagrams of an NACA 230 series tapered wing III with a 0.20-chord partial-span split flap: $\delta_f = 60°$; R = 4,500,000.

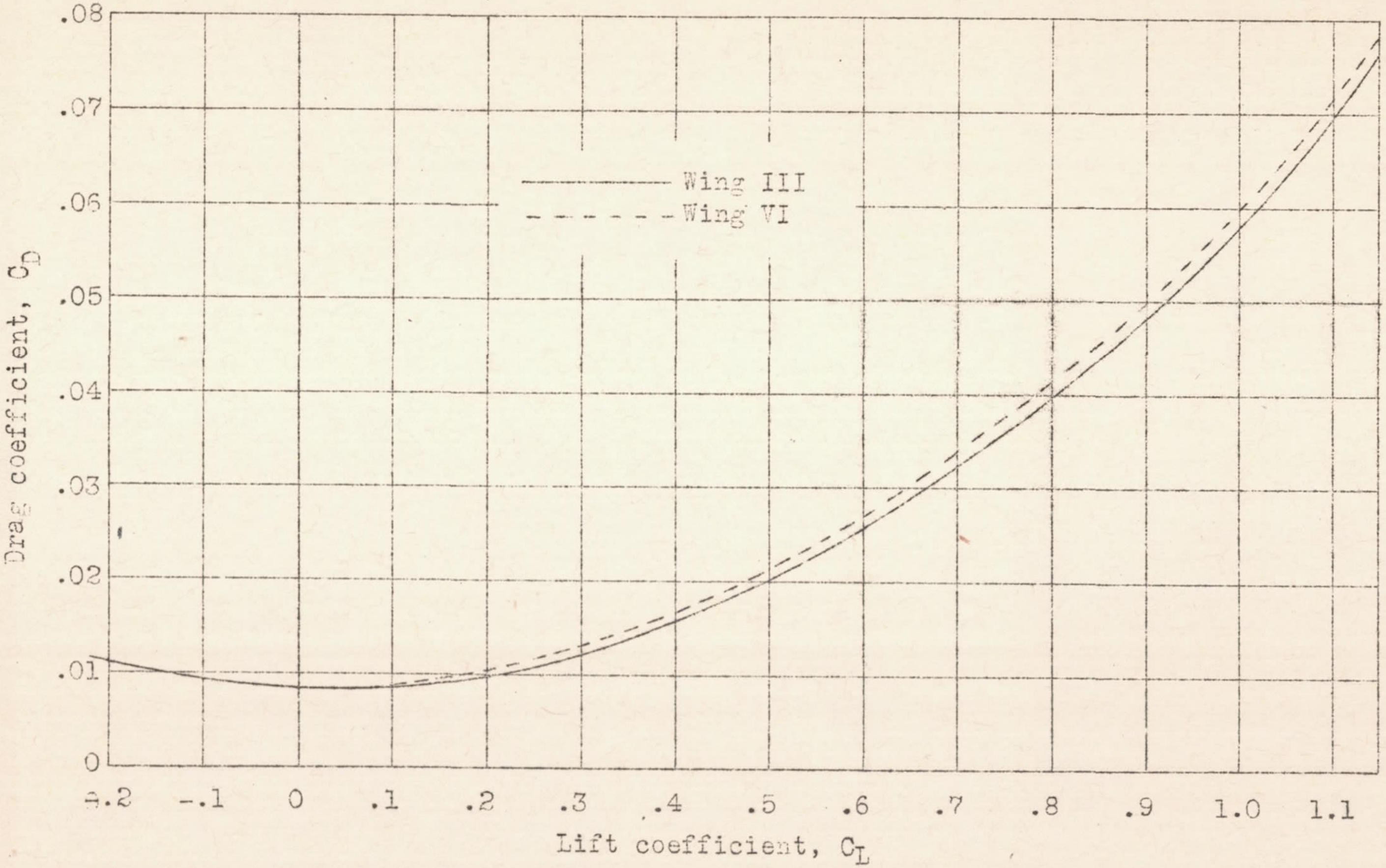

Figure 11.- Comparison of drag characteristics of wings III and VI; plain wing; R = 4,600,000.

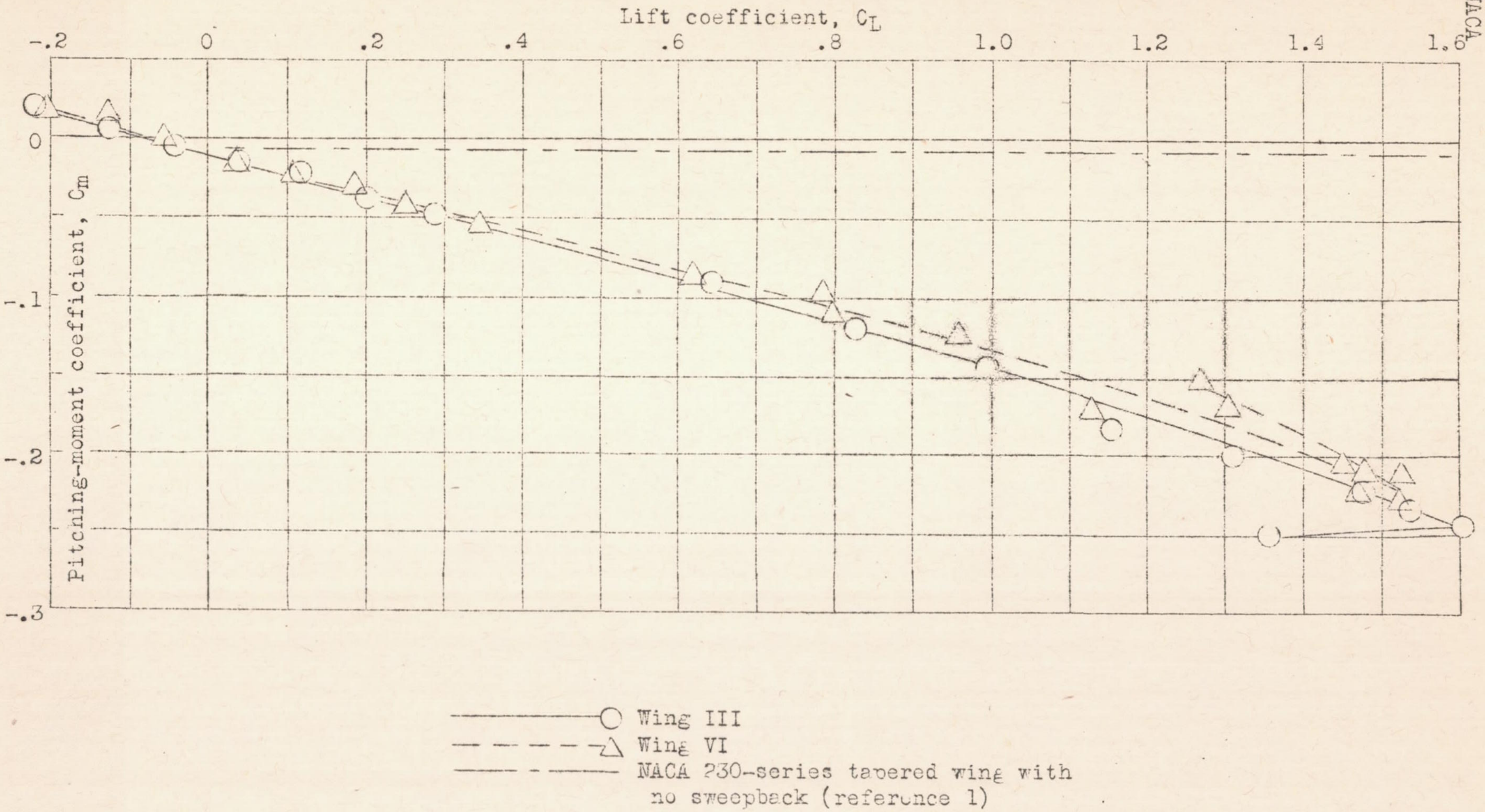

Figure 12.- Pitching-moment curves for wings III and VI; plain wing; R = 4,600,000.